

Use of Stone and Shell Artifacts at Balof 2, New Ireland, Papua New Guinea



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RESEARCH INTO RESIDUES remaining on the edges of prehistoric tools after use and their survival in the archaeological record has developed in the last few years. Current techniques for removing, preparing, and identifying these residues, though not completely straightforward, can readily be learned and applied (Fullagar 1986, 1988; Fullagar et al. 1992; Loy 1983, 1987, 1990; Loy et al. 1992). The aim of these studies has been generally to determine the materials on which tools had been used and their relative frequency as an indicator of site function. Our study attempted not only to fulfill this aim, but to investigate a further problem, namely whether a change in the raw materials from which tools are made is an indication of a change in the range of materials on which they were used. (For an Australian example, see Fullagar et al. 1992.)

We examined samples of stone and shell tools from a series of stratified excavation units from the rockshelter Balof 2, New Ireland. Specifically, we tried to falsify two null hypotheses. These were that: (1) the same range of residues occurred on tools made of all raw materials and, (2) the same range of residues continued to be deposited through time. Here we show that at Balof 2 neither the replacement of other fine-grained materials by obsidian nor the commencement of use of shell tools indicate different uses. A full account of this analysis is given in Barton (1990).

SITE AND SAMPLE

Balof 2 (Papua New Guinea National Museum site code EAB) is an overhang within a collapsed limestone doline about 2.7 km inland from Madina on the east coast of New Ireland, Papua New Guinea (Fig. 1). The site is at the inland edge of present-day gardens and plantations, and there is oral and material evidence that it was used as a refuge during World War II (1939–1945). Three seasons of excavation have been carried out by J.P.W., removing 9.1 m³ of deposit containing cultural material to a maximum depth of 1.8 m. Excavation was largely in 5-cm units (spits), with some of the material, including that discussed here, being wet-sieved

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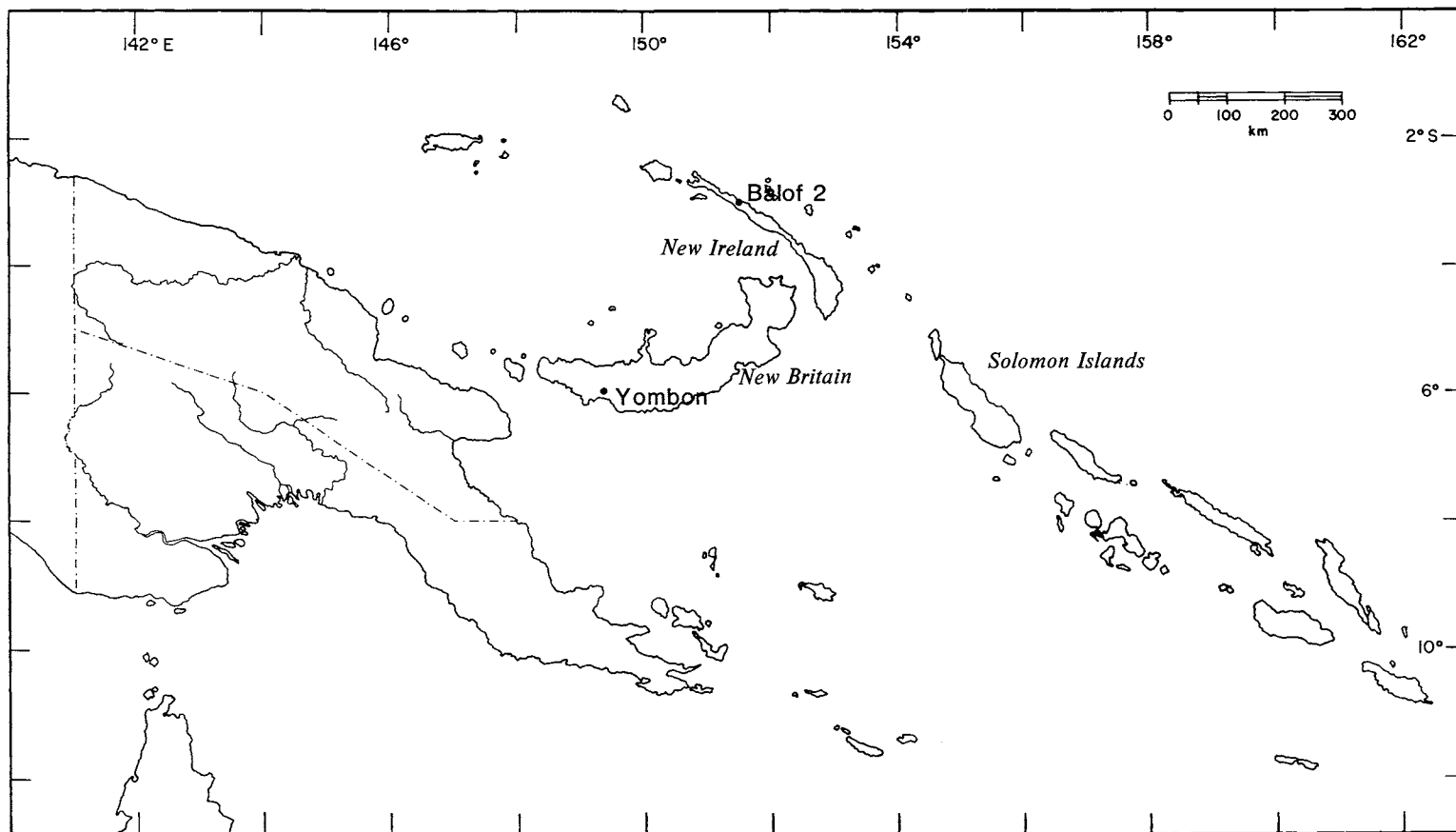


Fig. 1. Location of Balof 2 cave, New Ireland.

through 3-mm mesh. The earliest occupation is radiocarbon dated to $14,240 \pm 400$ B.P. (ANU 4848), and site use has probably been continuously intermittent since then. Certainly all microstratigraphy has been destroyed (McConnell 1992). Animal bone and marine shells constitute most of the archaeological deposit (Allen et al. 1989; White et al. 1991). A final site report is still in preparation.

Flaked stone artifacts, basically in the form of unretouched flakes and chunks, are present throughout the sequence, but number only 324 (White et al. 1991: table 11). They are made of a variety of raw materials including limestone, coarse-grained volcanics, fine-grained rocks (such as quartzites, cherts, and chalcedonies), and obsidian. Although the first two classes occur throughout the sequence, the occurrence of fine-grained rocks and obsidian is complementary, with the former occurring only in levels older than about 7500–10,000 years ago and obsidian after that date (White et al. 1991: table 11).

Analysis of the marine shells has also shown that broken pieces of venerid clams occur in all levels above those in which the fine-grained rocks are found, thus being contemporary with obsidian. Many valve edges from the site exhibited a “nibbled” pattern of edge breakage that appeared consistent with use of some kind (cf. Cooper 1988; Lima et al. 1986; Schrire 1982:38). These clam shell edges are large (up to 6 cm) and quite sharp; similar ones were seen by J.P.W. in use as vegetable peelers in New Ireland in the 1960s.

Our analytical sample came from two adjacent 50 by 50 cm excavation units, K61 and L61, removed in 1990. It consisted of six obsidian, 15 fine-grained stone, and 21 shell pieces, comprising, respectively, 60, 37.5, and 7.3 percent of the total in these squares (Table 1). In the case of both rock types, mostly larger pieces (>2 cm length) were selected. With the shell pieces, larger pieces up to 6 cm long, clearly unburnt and with nibbled edge damage, were chosen. Random sampling was not attempted. The sample of 42 artifacts contained 53 separate “edges.” These were defined as the cessation of utilization or retouch or where there was a change in direction of the edge, when viewed in plan, through more than 40 degrees within a distance of less than 1 mm (White 1969). Edges are the operational part of New Guinean tools (cf. White 1968, 1972), and use-wear and residues should be found on them.

WEAR AND RESIDUES

We determined at the outset to examine the sample for both use wear and residues and to accept residues as resulting from prehistoric use only if they were found on the same edge as use-wear. The simple reason for this was to avoid the possibility that animal and plant material present within the deposit could have become attached to the artifacts after deposition.

Any attempt to analyze both use-wear and residues on the same artifacts must, however, consider the contrary requirements of cleaning. Ideally, residue analysis should be conducted on artifacts removed from the ground with as much adhering matrix as possible, using sterile plastic gloves, immediately bagged, and subsequently handled as little as possible. Equally ideally, use-wear analysis often requires careful cleaning with sonic baths or acid and alkaline washes, all of which are designed to remove sediment and other adhering material, including residues relating to use. Our sample was wet-sieved in the field and dry-brushed and

TABLE 1. NUMBERS OF ARTIFACTS FROM SQUARES K6I AND L6I, WITH APPROXIMATE DATES

EXCAVATION LEVELS	OBSIDIAN			FINE-GRAINED STONE			CLAM SHELL			¹⁴ C DATES FROM EQUIVALENT LEVELS ^a
	ANALYZED	(EDGES)	TOTAL	ANALYZED	(EDGES)	TOTAL	ANALYZED	(EDGES)	TOTAL	
1										
2									7	
3	1	(1)	2				2	(4)	30	60 ± 150 B.P. (SUA2966)
4							2	(2)	9	
5	1	(1)	2						20	
6							2	(2)	27	
7									29	
8	1	(1)	1				2	(3)	24	
9							1	(1)	28	3120 ± 190 B.P. (ANU4972)
10	1	(1)	1				2	(2)	23	
11									20	
12									12	
13							1	(1)	10	
14	1	(1)	2				2	(2)	8	7680 ± 510 B.P. (ANU4849)
15							1	(1)	6	
16	1	(1)	2	1	(1)	2	2	(3)	6	
17									7	
18							2	(2)	7	
19						1			3	
20							1	(1)	3	
21				1	(3)	2				
22				1	(1)	1				10560 ± 230 B.P. (SUA2502)
23						6				
24				3	(4)	4	1	(1)	9	
25						5				
26				4	(7)	6				
27				1	(1)	6				
28				2	(2)	4				
29				2	(3)	3				
30										14240 ± 400 B.P. (SUA4848)
Total	6	(6)	10	15	(22)	40	21	(25)	288 ^b	

^aNo dates are from these squares. SUA2965 is from an adjacent 50 by 50 cm square; for other samples the correlation is indicative, not precise.^bOver half the shell fragments are burnt and smaller than 1 g.

labeled in the laboratory. Few large, distinct organic structures, required for successful incident light observation, were seen using this technique, but considerable quantities of residue were present and could be studied under transmitted light. The presence of residues hampered our observations of use-wear, but this could usually be found on the arris of edges or in the form of striae present in the residue itself.

Residues

Residue analysis is still a developing field, in which attention has been concentrated especially on the detection and determination of blood and collagen, though lipids and feather barbules have also been recorded (Fullagar 1986, 1988, in press; Loy 1983, 1987, 1990). There has been as yet no satisfactory explanation as to why these residues have been preserved on artifacts for thousands of years.

The detection of plant residues has been less thoroughly pursued, partly because of difficulties of identification under incident light (but see Fullagar 1988; Hall et al. 1989; Loy et al. 1992). Many residues are, however, visually distinctive under transmitted light microscopy. The main components of plant cells that may be distinguished chemically are found in the cell walls. Principally these are cellulose and lignin, which can be detected by staining with Toluidine blue O (Keeton and Gould 1966). Fundamental tissues present in plants include parenchyma, collenchyma, and sclerenchyma. This last includes fibers and the vascular cells, xylem and phloem, both of which are involved in conducting fluids throughout the plant. Xylem cells occur as tracheids and vessels, which are morphologically distinct. Two other major categories of plant residues that can be usefully identified are starch grains and inorganic crystals. Starch grains may be found in all parenchymatous tissue and appear luminous with a dark cross at the growth center when viewed under cross-polarized light. Inorganic crystals are usually composed of calcium oxalate or silica and often occur in long needle-shaped bundles called raphides. In conjunction with starch grains, they may be diagnostic of species, especially among the Araceae (e.g., Loy et al. 1992).

Use-wear

We searched for both macroscopic and microscopic ($>100\times$) use wear on both stone and shell artifacts. On stone, we found that wear consisted of edge fracturing, polish, striations, or rounding, following the main classes defined by Kamminga (1982) (Table 2). These were used to determine both the fact of use and, where possible, its nature and mode, whether transverse, as in scraping and whittling, or longitudinal, as in sawing.

TABLE 2. USE-WEAR ON EDGES

	N	SCARRING	STRIATION	ROUNDING	POLISH
Obsidian	6	6	5	—	—
Fine-grained stone	22	20	13	9	14
Shell	25	21	18	22	24

In contrast to stone, use-wear on shell edges has been little studied (Cooper 1988; Fullagar 1986; Lima et al. 1986). In the Balof 2 assemblage, it was apparent that most venerid clam edges, and no others, bore a series of very small, overlapping flake scars. These did not have the clear characteristics of feather, snap, and step fractures found on stone tools, but rather formed a continuously beveled edge. However, these edges exhibited the other main classes of wear found on stone. As a check to ensure that this wear was unlikely to be caused by the natural environment, we examined fragments of 93 pipis (class: Pelecypoda) from a local Sydney beach; only 25% were damaged and this damage was irregular in all but two cases. This was in clear contrast to the archaeological material, and thus we are satisfied that the wear we observed was caused by use.

METHODS

Using a stereo dissection microscope with incident oblique lighting, each sample was first checked for obvious flake scars, rounding (at up to 200×), and polish. The angle of striae in relation to the edge was noted for interpreting mode of use. The general color and texture of residues were recorded along with their identifications, such as starch grains, fibers, blood, or bone.

Some of the residue on each edge was then removed from the dorsal surface, using filtered water and a variable volume pipettor, and 10 µl was placed on a slide for analysis under transmitted light using an Olympus metallographic microscope. Features diagnostic of types of animal and plant tissue were photographed, and the approximate size of objects was calculated. Some macerated and fragmentary material was stained, using Iodine potassium iodide, Toluidine blue O, or Wrights stain. These assisted in distinguishing starch grains, cellulose, lignin, and animal matter.

RESULTS

Use-wear

All except one fine-grained stone and one shell artifact had use-wear of some kind on the dorsal or ventral edge or both (Table 3). The majority of this wear was derived from transverse activities, most likely scraping on soft materials low in silica. On shell, use-wear mostly consisted of beveling on the dorsal side of an edge. On two samples only, some light polish and a few flake scars were observed along the arris of the edge. One shell showed snapping a length of edge had occurred during use: such snaps were parallel to the edge, resulting in a curved fragment of shell.

TABLE 3. EDGES EXAMINED BY INCIDENT AND TRANSMITTED LIGHT

	INCIDENT	TRANSMITTED
Obsidian	6	6
Fine-grained stone	22	18
Shell	25	19

The mode of use of edges in all materials was primarily transverse, with some longitudinal. The materials worked appear to have been soft, because there are few flake scars on the edges (cf. Fullagar 1986:336–339). They were also low in silica because polish formation is weak (Fullagar 1991); bamboo is thus ruled out.

Residues

The presence of starches, parenchyma tissue, and sclerenchyma tissue (fibers, vessels, and tracheids), along with the absence of hair, collagen, blood, or films, strongly suggests that all deposited residues are from plants. Only four feather barbs attest to possible use of any of these tools on animals.

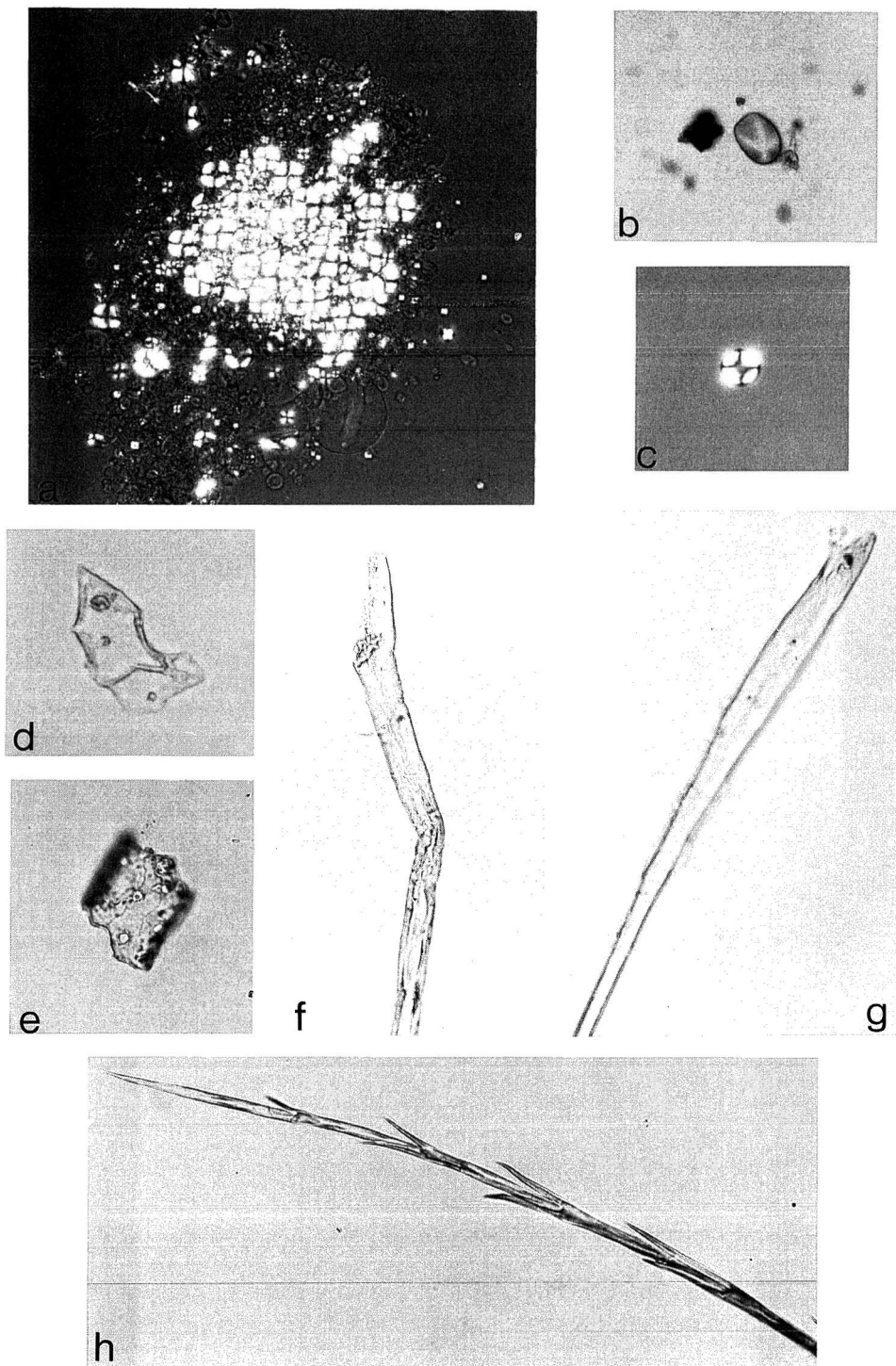
Incident light observations revealed starchy plant material or fibers or both on at least half of the fine-grained stone and shell artifacts, but none on the obsidian. However, unidentifiable residues were noted on all edges, with an orange-colored residue and a “cake crumb”-like residue being the most common.

Many fibers observed were modern synthetic contaminants: these were not recorded in detail. The others were all incomplete (torn) cellulose. The starch grains were mostly round and 9.5–12 μm across, though a few attained 50 μm . They were compared with grains from seven species of *Dioscorea*, ten aroids including *Alocasia macrorrhiza*, *Colocasia esculenta*, and three *Cyrtosperma* species, and two species of *Ipomoea*—*I. batatas* and *I. costata*, all supplied by T. Loy from his reference collection. The round shape excludes *Dioscorea* species because these generally are elliptical or pear-shaped (Ayensu 1972). In size they are slightly below *Ipomoea*, but are much larger than the taro *Colocasia esculenta*. There were no raphides, which are common in most aroids (Sakai 1979) and known to occur in yams (Ayensu 1972). One shell tool carried tissue consisting of thick-walled, rectangular cells, probably from a woody plant. More detailed observations were not possible with incident light because the resolution was not very high (cf. Fullagar 1986:207; Webb 1987:65).

Transmitted light observations proved to be much more revealing, and despite the fact that this process requires some of the residue to be removed from the artifact we strongly recommend its use for more detailed analyses. The residues we recorded can be categorized as: starch grains, lipids and macerated cellulose tissue, parenchyma tissue, sclerenchyma tissue (xylem and fibers), and feather barbules. We discuss each in turn.

Starch Grains—These are mostly round and generally 9.5–12 μm in diameter, with a few as large as 50 μm (Pl. Ia,c). Most have a well-defined extinction cross under polarized light. Based on the shape and size, we consider that most grains are derived from a group of aroids, namely *Cyrtosperma merkusii*, *Alocasia macrorrhiza*, and *Xanthosoma sagittifolia*. The first two of these occur in New Ireland but the last does not, except perhaps as a very recent introduction from South America (Hay 1990). Hay considers that the distribution of all three species probably indicates human dispersal, but noted that there is no variation in the grains of domestic versus wild plants.

Some of the larger grains fall within the *I. batatas* range, but the mean size is too small (T. Loy, pers. comm.). Large, pear-shaped grains, characteristic of *Dioscorea bulbifera* and *D. rotunda*, were noted, along with other grains, on one fine-grained stone and one shell tool in spit 16 (Pl. Ib).



Pl. I. Examples of plant and animal residues observed on various artifacts from Balof 2, New Ireland: *a*, starch grains on obsidian, polarized light, $\times 160$, L61/10; *b*, *Dioscorea* sp. starch grain on fine grain, $\times 160$, K61/16; *c*, starch grain on obsidian, polarized light, $\times 160$, same specimen as *a*; *d*, parenchyma cell on obsidian, showing cell wall, $\times 400$, L61/3; *e*, vessel element on fine grain, showing simple pitting, $\times 400$, K61/26; *f*, upper section of tracheid on fine grain, $\times 160$, L61/26; *g*, feather barbule, base at top of picture, on fine grain, $\times 400$, L61/26 (not the same as *f*); *h*, downy feather barbule on fine grain, $\times 400$, same specimen as *e*.

Based on the ethnographic record and many interpretations of Near Oceanic prehistory (e.g., Spriggs 1982; Yen 1990), we expected to find many grains of *Colocasia esculenta*. These are very small, and, notably, the arms of the extinction cross intersect at 90° under incident light but cross at different angles under transmitted light. The reason for this is not known (T. Loy, pers. comm.). We found no such grains.

Cellulose and Lipids—Both of these residues occurred in quantity. Cellulose was macerated and contained no cellular structure. Lipids were not further analyzed by us, but their composition could be determinable by gas chromatography. The lack of structure in much of this tissue suggests that it is derived from fleshy portions of plants.

Parenchyma Tissue (Pl. Id)—Parenchyma cells occur in all parts of plants, so their presence is unremarkable. However, their association with large quantities of starch grains again indicates a derivation from the fleshy portions of a starchy tuber. Conversely, the absence of collenchyma cells, found mostly in leaves and stems, supports this interpretation.

Sclerenchyma Tissue—Xylem vessel elements were identified (Pl. Ie, f). These occur in aroid and yam tubers but are not known in the leaves of aroids (Hotta 1971). Thickened extraxylary fibers with conspicuous spiral and radial thickening, scalariform pitting, and a thin lumen were noted on two obsidian, three shell, and two fine-grained stone artifacts, all but one from spit 16 and above. Such fibers were seen in the control preparations of yam, but were not noted in the comparative sample of aroid tubers.

Feather Barbules (Pl. Ig, h)—Four downy feather barbules were found on three artifacts (two fine-grained stone and one shell). Their morphology suggests anseriform, with ducks being the most likely (Day 1966:214; A. Rowell, pers. comm.). All feathers occurred on edges along with plant tissue.

Other Residues—Raphides, needlelike crystals of calcium oxalate, were present in all control samples of *Alocasia* and *Cyrtosperma* species, but were not seen in any archaeological samples (cf. Loy et al. 1992). The reason for this absence is not known. Absent also were any lignified woody cells. This is contrary to the incident light result and may indicate that residue fragments were too large to be taken up into the pipette tip.

In summary, the presence of parenchyma or starch or thickened fibers or all three seen using transmitted light is evidence for use on tubers of all of the obsidian samples, 88% of shell tools, and 68% of fine-grained stone tools.

DISCUSSION

In this section we discuss some of the problems and implications of our results.

Contamination

It has sometimes been claimed (e.g., Brown 1988) that tool edges may accumulate residues from the surrounding soil, and thus the presence of these does not indicate

human use. However, we found residues only on the edges of tools, which seems an unlikely degree of selectivity for a postdepositional contaminant. Further, we noted that animal bones are a major component of all levels at Balof 2 and would therefore expect animal tissue to be at least a common contaminant if that process was occurring. Finally, we do not believe that wet-sieving would have removed only the animal residues; consequently, their absence, like the universal presence of plant tissue, is real.

Obsidian

The recorded ethnographic uses of obsidian (Parkinson 1907; Specht 1981) in New Ireland and New Britain do not include tuber processing. But it has been noted that prehistoric tools from Yombon, New Britain, were used for this (Brown 1988), and Fullagar (in press) has proposed that slicing starchy tubers was a major function of obsidian stemmed tools from north-central New Britain. It is generally argued (e.g., Specht 1981:346–347) that obsidian was desired for the sharpness of its unretouched edges for uses mostly related to the human body, and all of the ethnographic record is consistent with this. The archaeological record is not. We suggest either that the ethnographic record is flawed, possibly through gender bias, or that the major uses of obsidian have changed in the recent past. We incline to the first view.

Taro

Colocasia esculenta is at present a staple crop in New Ireland and common throughout much of Oceania. It has been demonstrated to be of considerable antiquity (Loy et al. 1992) and is probably, in fact, indigenous (Coates et al. 1988; Yen 1990, 1992). Because it was used by people in the Solomon Islands 25,000 years ago or more, its absence from our New Ireland sample is surprising. It is possible that our sample is too small or some local conditions are responsible or—though we do not believe this—our methods are in error in some way. Further investigation of this problem is clearly warranted.

CONCLUSIONS

We started this investigation with two null hypotheses. We expected to disconfirm them, but failed to do so. Both the use-wear patterns and the plant residues remaining on tool edges show that tools made in three different raw materials were all used for the single job of tuber processing and that the tubers involved were mostly a restricted range of aroids. This finding of a single pattern of artifact use over a period of some 14,000 years seems to be inconsistent with the ethnographic records.

These data have some implications for the use of the Balof site. Attention has already been drawn (White et al. 1991:56–57) to several unusual features of the site compared with others in New Ireland (Gosden and Robertson 1991; Marshall and Allen 1991). These include the heavy concentration (44% of number of identified specimens [NISP]) on one animal, *Phalanger orientalis*; the restriction of marine shellfish almost exclusively to five small species primarily collectable near or above

high-water mark; and the small number of stone artifacts of any kind. All these suggest a site in which a limited range of activities was carried out. No wide-ranging shell collecting, very little fishing or birding, and a good deal of animal collecting (bats and rats total 48% of NISP) mark the site as one in which many would see women's and children's activities playing a major role. The problem is compounded by having at this time no clear markers of any major changes in subsistence or exchange predicted by some (e.g., Bellwood 1991) to have occurred about 3500 years ago. A few scraps of pottery in levels dated less than 2000 years ago confirm that changes documented on the nearby coast (e.g., White and Downie 1980) made their mark, but they did not alter the overall pattern of use of Balof 2. It is tempting to see this use as similar to that remembered by some current inhabitants of nearby Madina village—a refuge in wartime, when regular food was hard to obtain and recourse was had to alternatives that could be collected safely.

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ABSTRACT

We examined the use-wear and residues on a sample of six obsidian, 15 fine-grained, and 21 clam-shell artifacts from Balof 2 cave, New Ireland. Only residues associated with use-wear were accepted as deriving from use. The majority of residues are of plant tissue, notably starch grains from the aroids *Cyrtosperma merkusii*, *Alocasia macrorrhiza*, and *Xanthosoma sagittifolia*. Some *Dioscorea* grains were also noted, but not *Colocasia esculenta* or *Ipomoea batatas*. Some feather barbules were recorded. Methods of analysis and implications of the results are discussed. KEYWORDS: residues, Papua New Guinea, shell artifacts, stone artifacts.